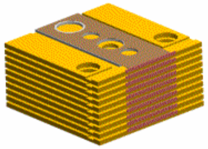


Development of High-brightness Diode Laser Pump Modules for LIDAR Applications

EST Conference June 24, 2003

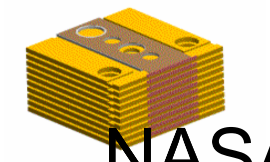
Paper B1P9

PI - Renny Fields

Co-I's Todd Rose, David Hinkley, Jerome Fuller, James Swenson – **Aerospace Corp**.

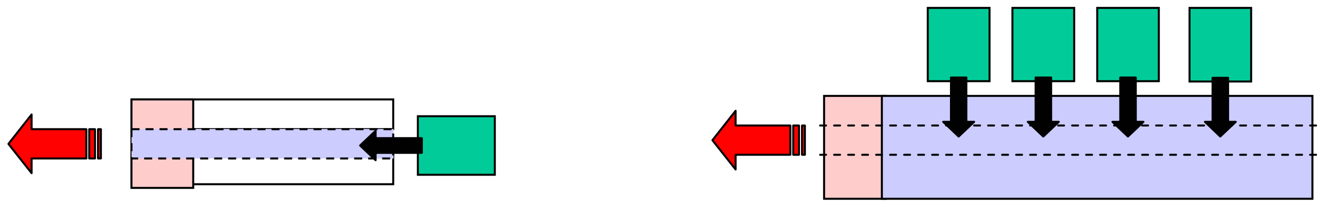
Tuomo Konnunaho, Jukka Kongas, Tiina Amberla, and Mervi Koskinen – **Coherent Tutcore**

Mark Mondry, Jim Harrison, and Paul Rudy – **Coherent Semiconductor Division**



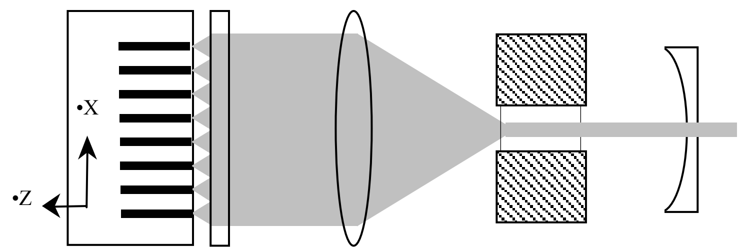
NASA-ESTO High Efficiency Laser Development

Longitudinal vs. Transverse Pumping



- High intensity-high brightness source will provide 2-4 times higher efficiency in passive Q-switch format

Implementation Approach



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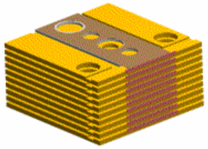
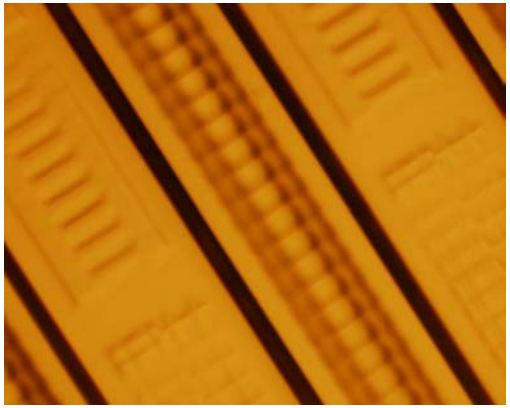
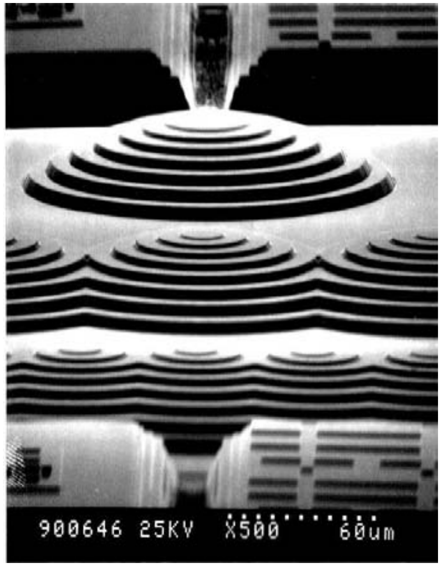
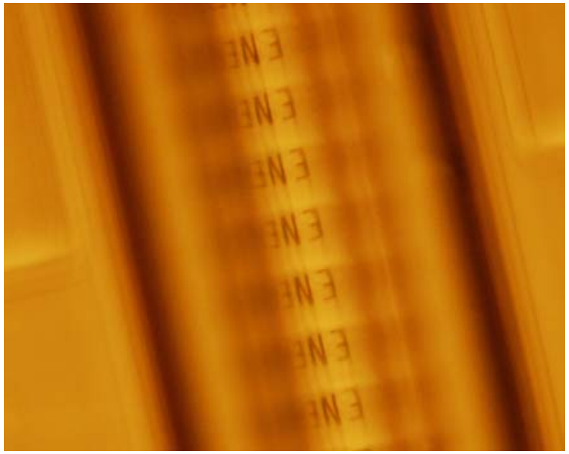
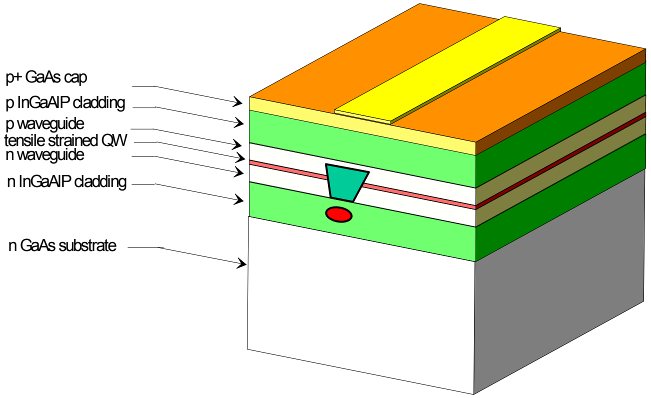


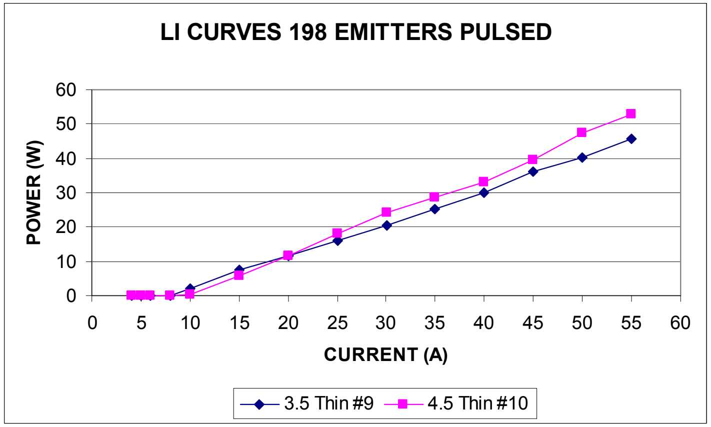
Lens and Diode array production











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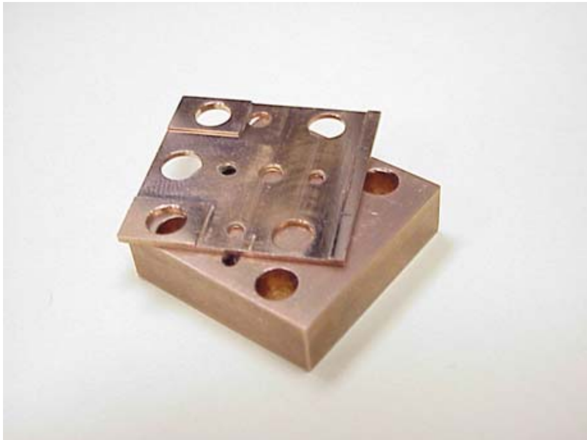
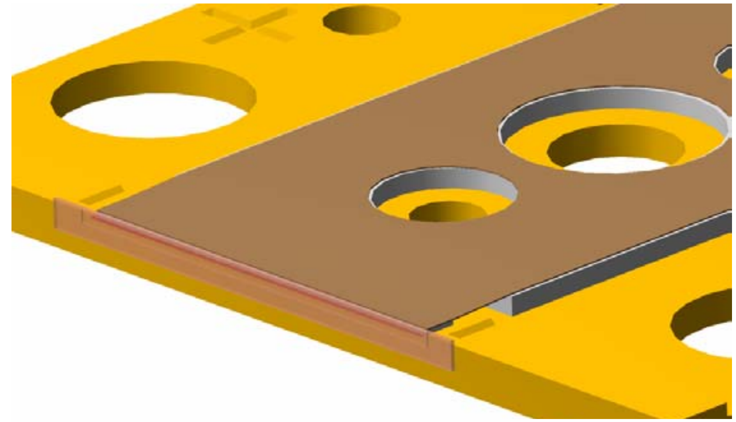
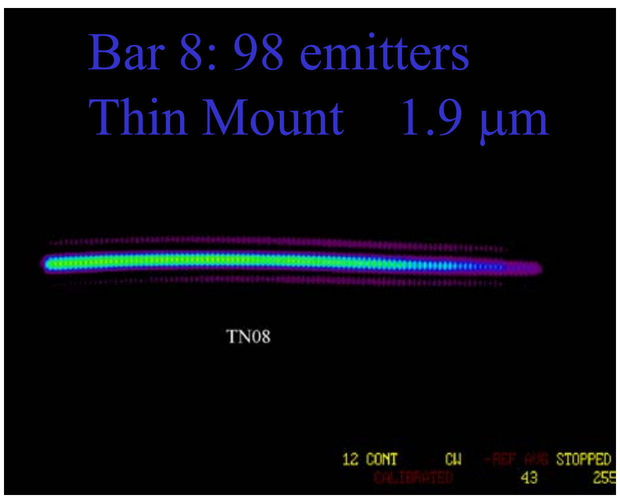
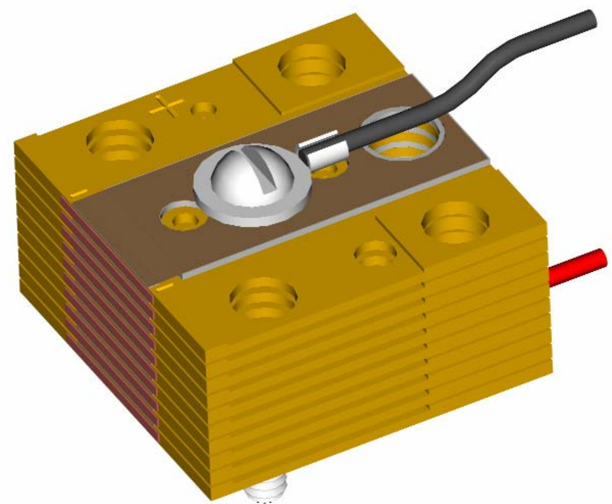
Bar/Lens Mounting and Stacking









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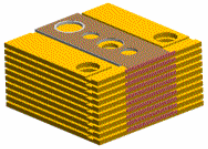

Conclusions from early efforts

- Must conform to a commercial process
- “Smile”; bar flatness is a key issue in yield
  - Copper tends to result in 50% yield (< 3 μm) for 1 mm thick submounts
- Emitter (50 μm) pitch also affected by submount choice – different CTE can distort emitter positions to several microns over 1 cm bar
- For current effort – 200 emitters (50 μm pitch), 4.5 μm stripe width

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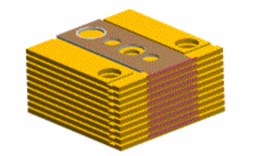


Cavity length comparison

Uncoated device cavity length comparison:

830nm single mode material, 2.5um emitter

(Slope and P kinkfree can be multiplied by 2 when normal AR/HR coating will be applied)

	slope (W/A)	Jth (mA)	Rs (Ohm)	P kinkfree (mW)
SQW MESA	0,5	17	3	60
DQW SAS 1,0mm	0,49	24	1,9	52 *
SQW SAS 1,0mm	0,45	18	2,1	62
DQW SAS 1,5mm	0,42	39	1,2	80
DQW SAS 2,0mm	0,38	49	1	85

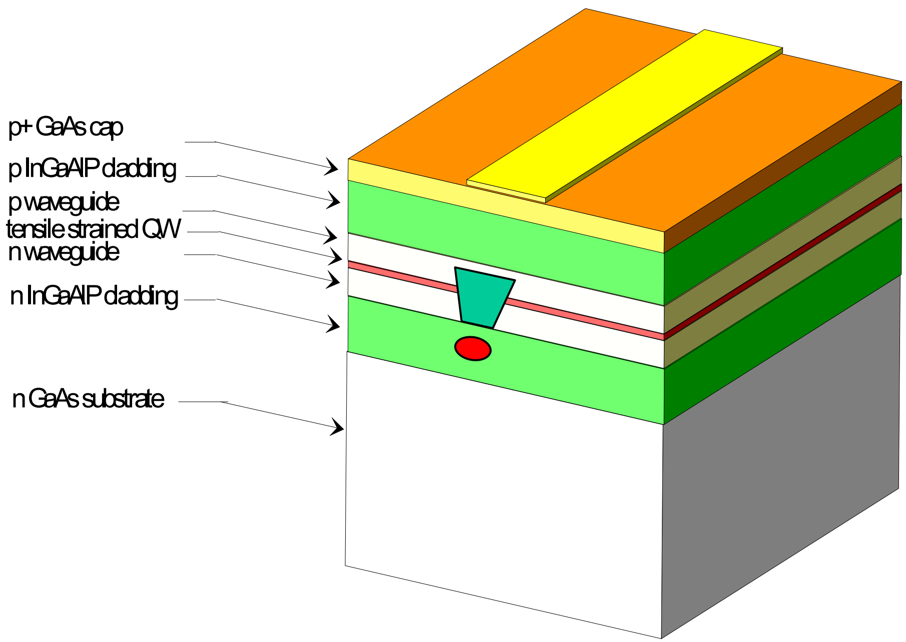
DQW SAS results with 1,0mm, 1,5mm and 2,0mm cavity lengths are from same wafer

*** Best obtained results give 62mW**

SAS structure

Benefits

- lateral index step defined by overgrowth on a groove
- critical dimensions accurately determined with epitaxy
- self aligned process
- large contact area, low series resistance



Disadvantages

- overgrowth quality critical to device performance
- overgrowth typically done by MOCVD, difficult to do with MBE
- regrowth occurs on an area that is relatively close to active region, hence reliability concerns

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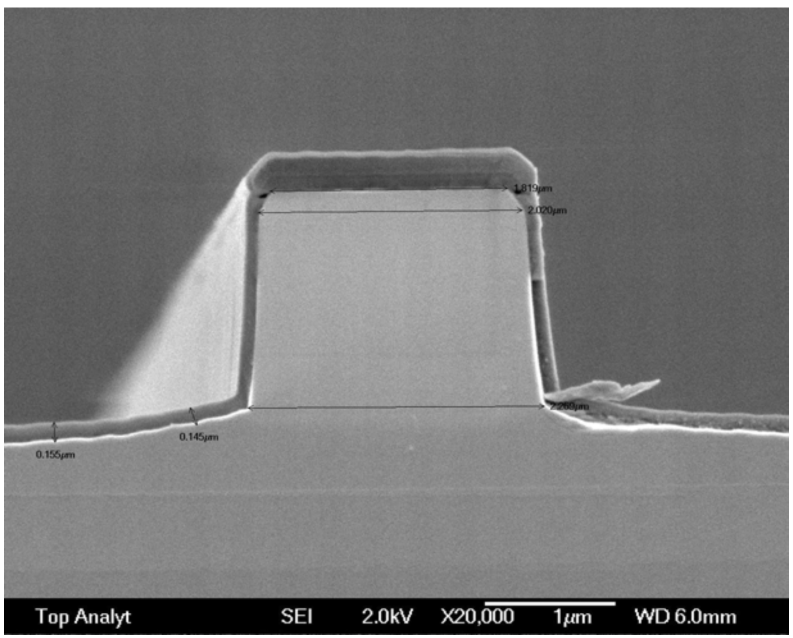
Ridge structure

Benefits

- only single epitaxy required for active area, hence reliability expected to be inherently better than SAS
- regrowth by MBE or MOCVD is not necessary



Disadvantages

- contact area defined by mesa surface area
- self-aligned process difficult to realize (but we have done it)
- mesa etching depth is a critical parameter (but we have a method that gives us pretty good control)

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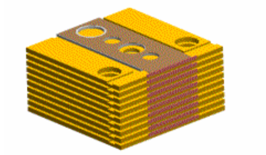
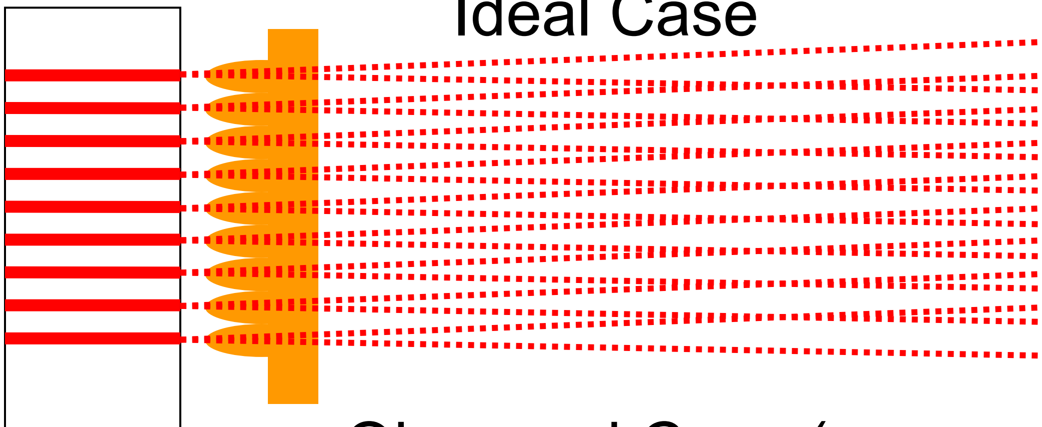


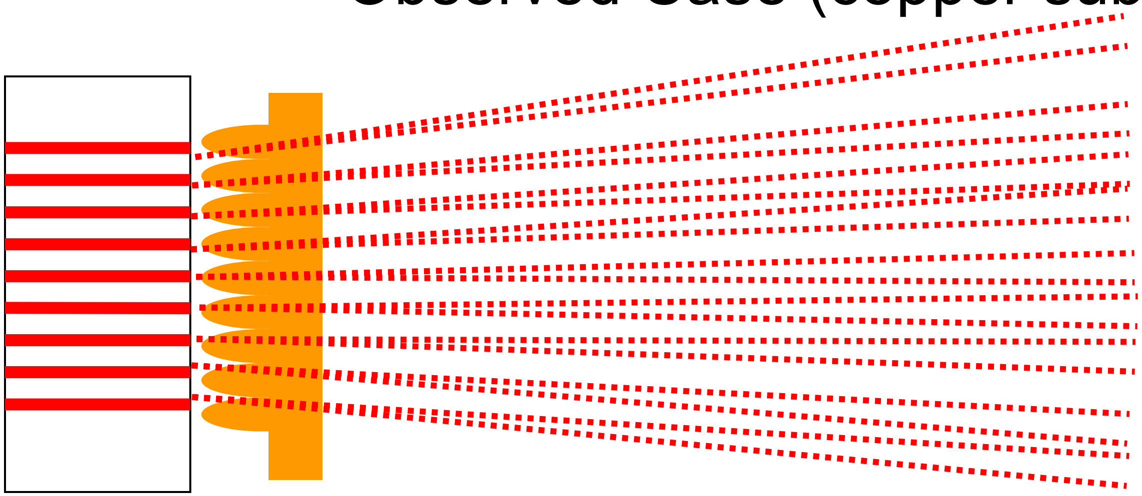
Impact of Pitch Variation

Ideal Case



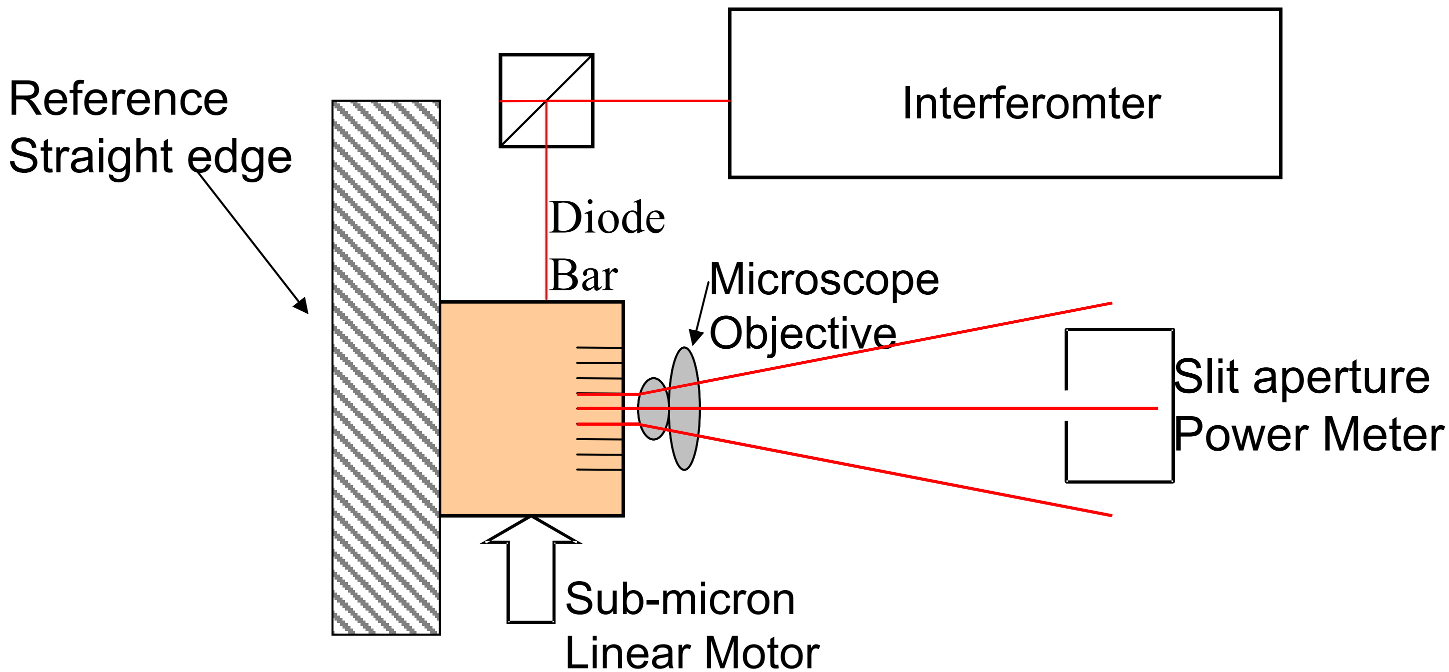
End-end emitter distance equal to end-end lens distance within 1 micron over 1 cm

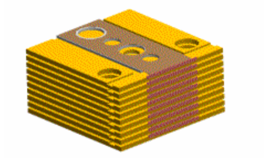
Observed Case (copper submount)



End-end emitter distance different than end-end lenses by ~ 6 microns over 1 cm

Pitch measurement unit





Thin Conduction Cooled Mount Materials Choices

current material

recommended materials

Property	Units	OFC copper	CVD SiC	BeO	Cu/W	6061-T6	GaAs	Indium	Stainless
electrical resistance	Ohm cm^2/cm	10^{-6}	10^{-2}	10^{14}	10^{-5}	10^{-6}		10^{-6}	10^{-6}
thermal conductivity	W/mK	391	250	250	200	167	55	84	19
elastic modulus	x 10^6 lb/in^2	17	68	50	40	10	12	1.8	30
thermal expansion	x 10^{-6}/°C	17	2.2	8	6.5	23	5.8	24.8	17.3

Too large!

Target CTE

- Good thermal and electrical conductivity are needed
- High elastic modulus
- Matched thermal expansion to semiconductor is good

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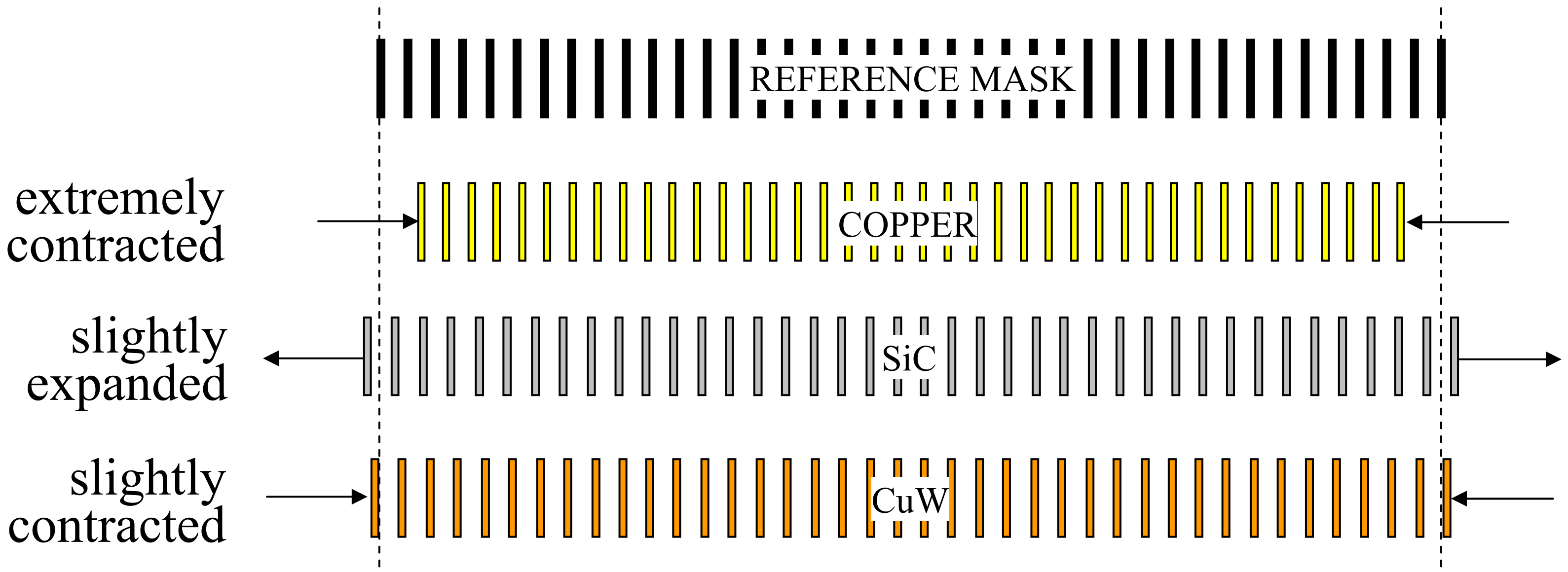
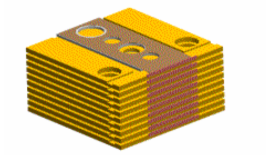
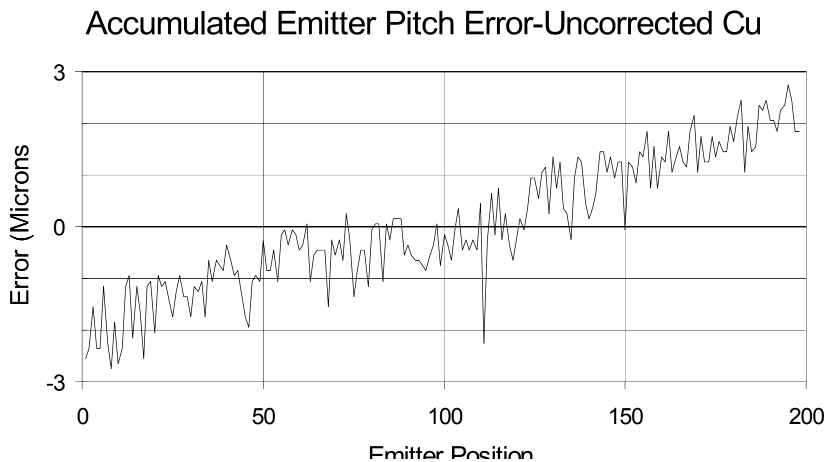
Diode Bar Emitter Pitch Variations due to Submount Material

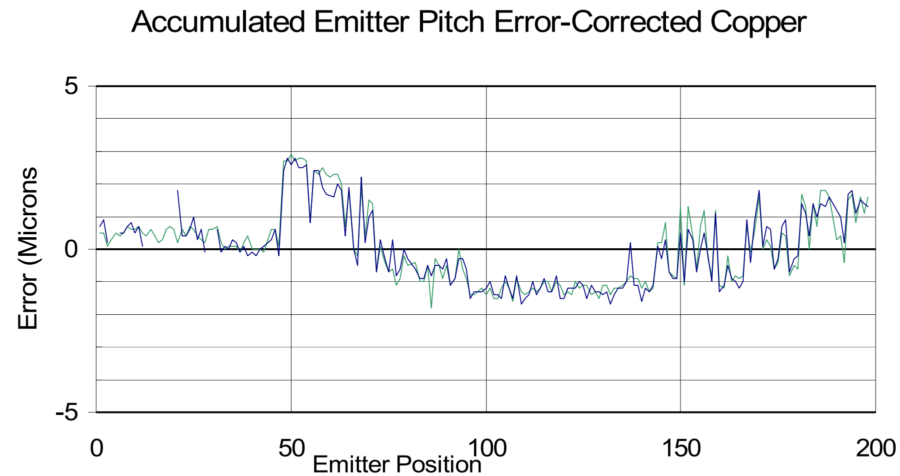


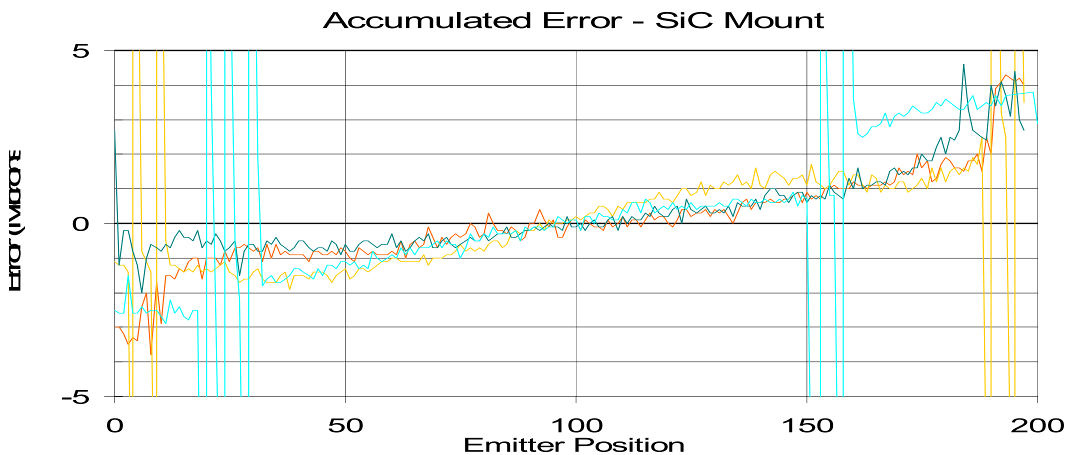


Contraction vs. Stretching is NOT Uniform

- GaAs appears to buckle at random points







- SiC stretches the wafer upon bonding which provides more uniform displacement - lowest RMS shift

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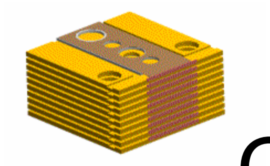
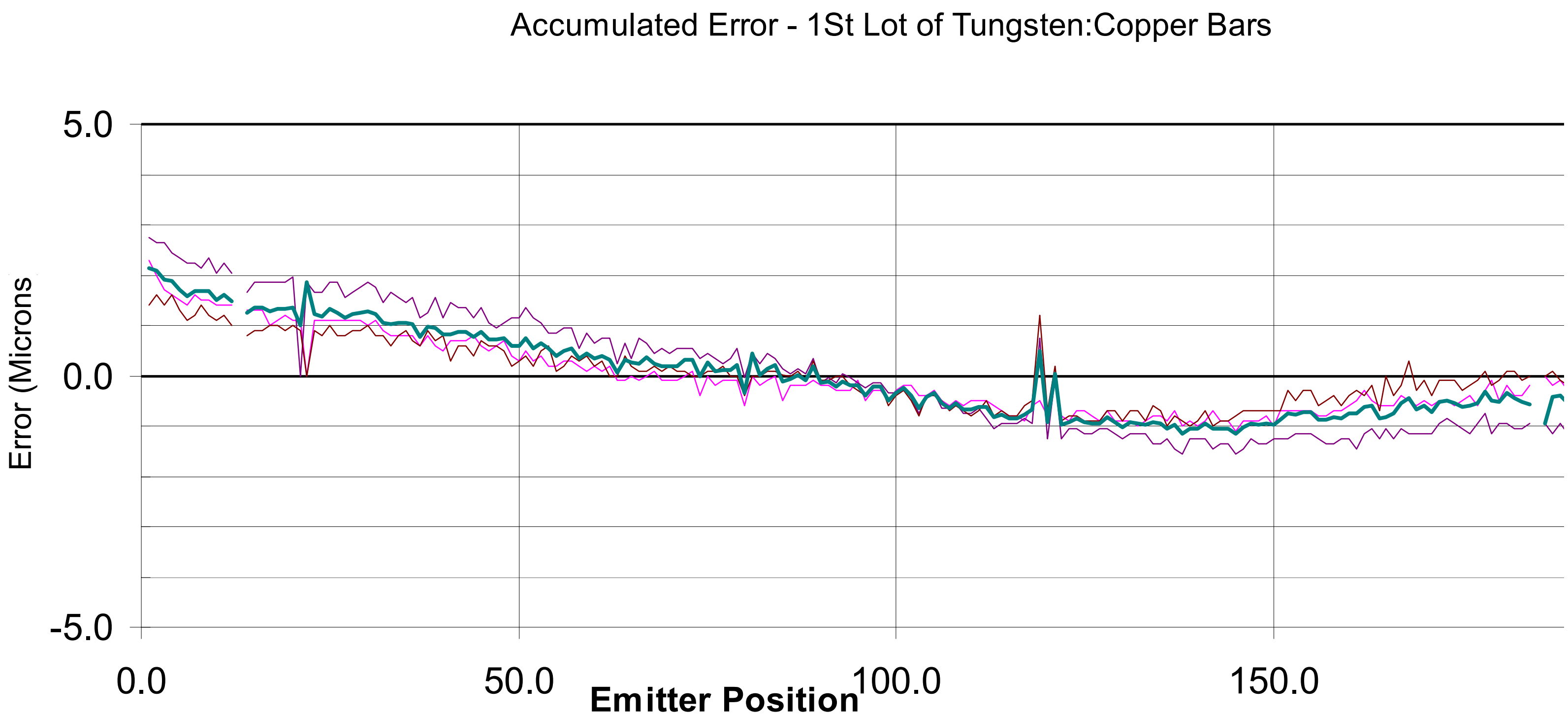


Cu:W shows lowest pitch error with uncompensated mask



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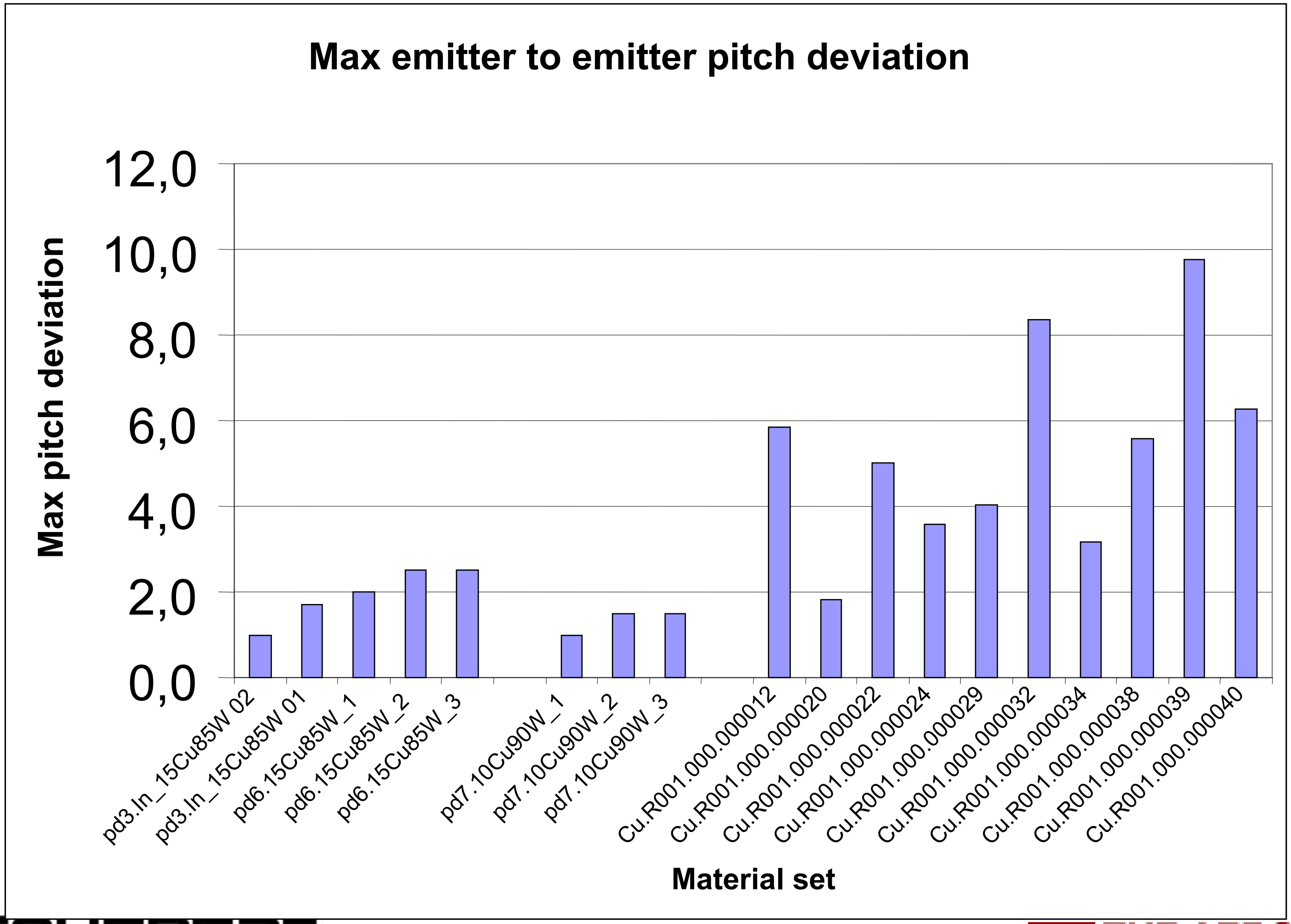
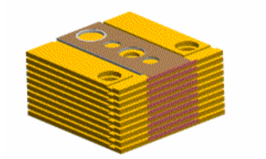
Pitch control vs. materials





Smile Data for Various Mounts

SiC mount		Cu mount		CuW mount	
Bar #	Smile (μm)	Bar #	Smile (μm)	Bar #	Smile (μm)
1	1.0	8	3.4	1	3.8
2	0.7	9	2.2	2	3.1
3	1.7	16	1.2	3	1.2
4	0.5	20	4.6		
5	1.0	22s	0.9		
		22t	1.2		
		24	1.2		
		26	3.9		
		84	0.9		
Avg. = 1.0		Avg. =2.2		Avg. =2.7	

- SiC demonstrates most optimum smile
- Significant improvement on Copper
- CuW shows large smile due to process errors

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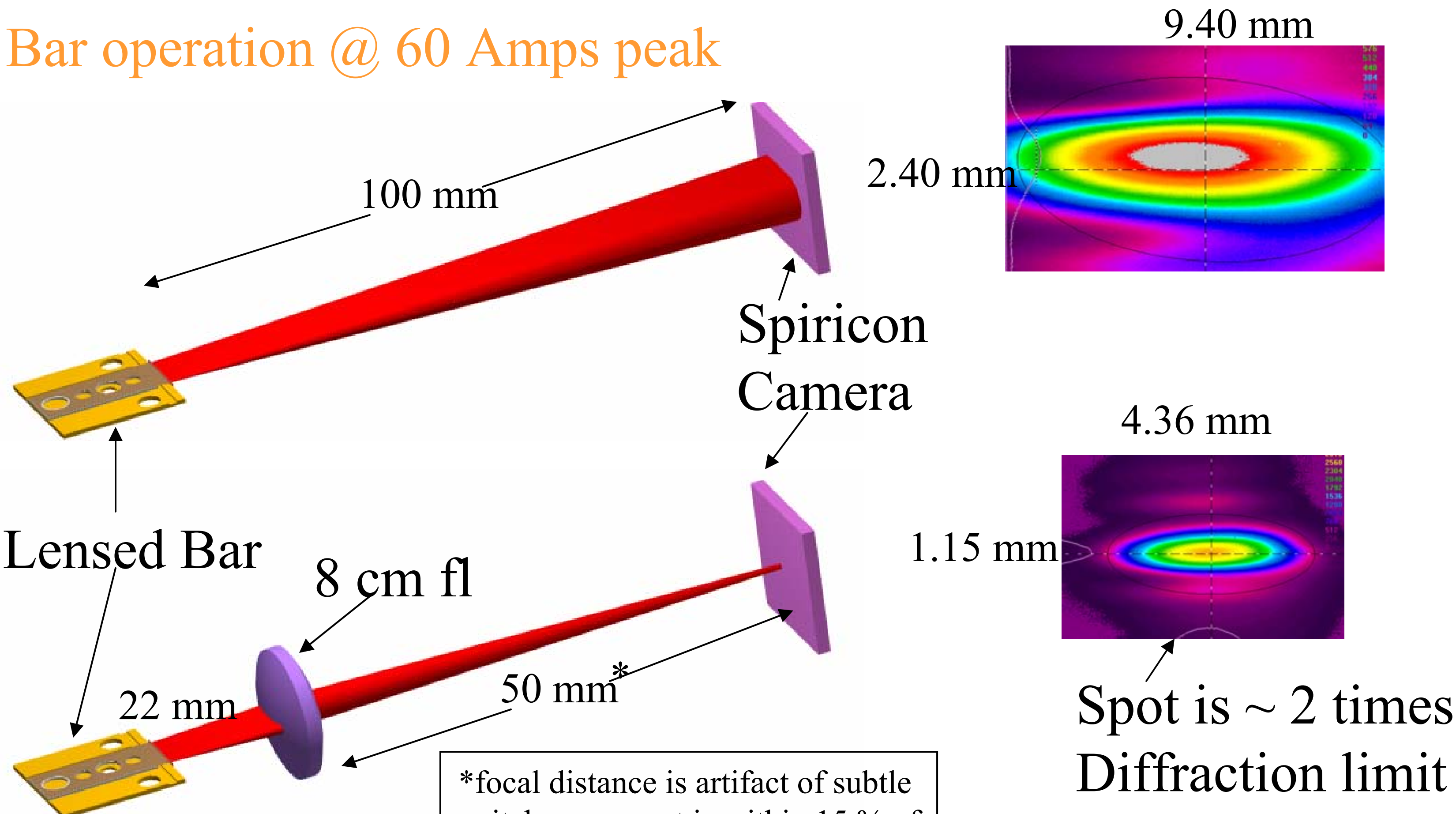
Lensed SiC Bar meets Brightness Goal

Bar operation @ 60 Amps peak



*focal distance is artifact of subtle pitch error, spot is within 15 % of min. diameter over several cm's

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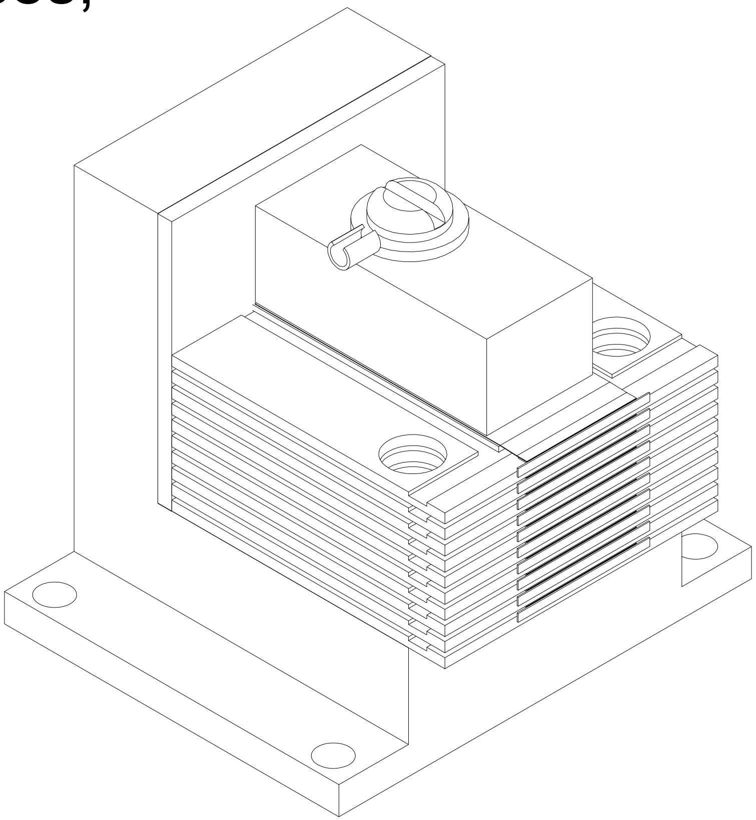
Further Integration Efforts

- Because of the value of lenses, inability to remove lenses after bonding, and low slope efficiency of delivered material we chose not to epoxy lenses to bars at this point in the effort
- Accurate lens mounting has been demonstrated
- Lenses will be bonded and bars will be stacked when good bars are delivered



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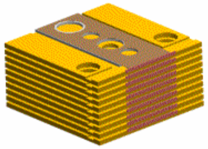

Summary

- We have developed a path to cost effectively produce ideally pitch-matched lenses and diode bars
- Current path is to mount on CuW due to cost and delivery– still have concern over CuW smile
- Most optimum system may be SiC, but would entail more cost per mount, and mask adjustment for the emitters
- By conclusion of the program expect to have a stack of 10 bars with similar spot size to that demonstrated for the single bar (600 W peak power)

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